Coming of age in gesture

Masson Carro, Ingrid; Goudbeek, Martijn; Krahmer, Emiel

Published in:
Proceedings of the 4th GESPIN - Gesture & Speech in Interaction Conference

Publication date:
2015

Document Version
Peer reviewed version

Coming of age in gesture: A comparative study of gesturing and pantomiming in older children and adults

Ingrid Masson-Carro, Martijn Goudbeek, Emiel Krahmer

Tilburg center for Cognition and Communication (TiCC), Tilburg University, The Netherlands

i.massoncarro@uvt.nl, m.b.goudbeek@uvt.nl, e.j.krahmer@uvt.nl

Abstract

Research on the co-development of gestures and speech mainly focuses on children in early phases of language acquisition. This study investigates how children in later development use gestures to communicate, and whether the strategies they use are similar to adults'. Using a referential paradigm, we compared pantomimes and gestures produced by children (M=9) and adults, and found both groups to use gestures similarly when pantomiming, but differently in spontaneously-produced gestures (in terms of frequency of gesturing, and of the representation techniques chosen to depict the objects). This suggests that older children have the necessary tools for full gestural expressivity, but when speech is available they rely less on gestures than adults, indicating both streams aren't fully integrated yet.

Index Terms: Gesture, pantomime, representation techniques, development, older children, adults.

1. Introduction

The co-development of speech and gestures has been thoroughly studied, especially regarding the first years of life. This is not surprising, given that gestures are an invaluable source of information when it comes to studying cognitive development [1]. First, looking at the development of gestures helps researchers understand how both modalities (gestures and speech) become an integrated system in spontaneous talk [2], [3], [4]. Second, looking at the type of gestures produced by children provides researchers with a "window" into the development of conceptual representations, and (arguably) the shift towards symbolic thinking (e.g., [5], [6], [7]). Typically, these studies have been conducted as children learn their first words and transition into the two-word stage [3]. However, few studies have addressed gesture development after this phase [4], and even less studies have looked at how older school-aged children (e.g., after the age of 6) produce gestures –despite the fact that the gestural system is thought to keep developing until adolescence [2].

In the present paper we look at how older children use gestures in referential communication, and we compare their performance to that of adults, with the aim to find out not only whether children and adults accompany their descriptions with gestures to a similar extent, but also whether their gestures exhibit similar patterns, in terms of the representation techniques [8] used to represent objects. Analyzing these techniques provides valuable information about the iconic strategies used by children to translate mental representations into gestures, and often the choice of technique can be seen as an indicator of cognitive development (e.g., see [6]).

Furthermore, we investigate gestures in two communicative modalities, namely speech and gesture, and gesture-only (or *pantomime* [2]), to assess how both age groups use representation techniques to express meaning when gestures play a primary, or a secondary role in communication.

1.1. Becoming a "mature" gesturer

Several studies have helped define a series of stages in the co-development of gesture and speech. It is well-documented that children start producing gestures before they start producing their first words [2], [9], [3], [4]. At this stage, children combine vocalizations with deictic gestures, produced to direct their caregiver's attention towards objects in the environment. Around the age of twelve months, children start producing their first words, and their first iconic gestures [9], [3]. Importantly, at this age there is little integration of the gestural and speech modalities, with children referring to objects by either producing a gesture or uttering a word, but generally not both at the same time. The first gesture-word combinations emerge around 14 months, preceding (and perhaps facilitating) the onset of two-word combinations, provided that these are not simply gesture-word co-occurrences, but that they together convey idea units [3], [10]. Not many studies have systematically analyzed how gestures and speech continue to co-develop after the two-word stage, with a few exceptions. For instance, Mayberry and Nicoladis [11] conducted a longitudinal study following 5 boys between the ages of 2 and 3;6 years old, and showed that already at 2 years old children used gestures in combination with speech, but there were differences regarding the type of gestures children produced, in comparison with adults. For instance, these gestures remained deictic in their majority (in contrast to adults, who produce deictic gestures to a fairly low extent), with iconic and beat gestures increasing with age as language constructions became more complex. After this stage, the production of iconic and beat gestures continues to develop throughout the third, fourth and fifth years of life [2].

Stefanini, Bello, Caselli, Iverson and Volterra [12] looked at how children aged between 2 and 7 years represented objects and actions in gesture during a naming task. Their findings suggested that the production of spontaneous gestures decreased with age, but did not disappear (even at the age when children had sufficient vocabulary to simply name the objects). This decrease in gesture production was particularly pronounced for deictic gestures, which were the most produced gesture type in all age categories. This indicates that there is a progression, as children age, towards producing less deictic and more iconic gestures. But, how does their gesturing compare to adults'? In a narrative context, Alibali and colleagues [13] examined how children aged 5 to 10 gestured while retelling a cartoon, as compared with college students. They found no significant differences in the amount of gesturing between adults and children, but they did find differences in terms of how "redundant" gestures were in relation to speech, with children producing less redundant speech-gesture combinations than adults. In sum, these studies suggest that the relationship between speech and gesture is not stable throughout childhood, and keeps on changing during later developmental stages, possibly until adolescence [2].

1.2. Representation techniques and symbolic thinking

So far, we looked at the amount and type of gestures produced by children during early linguistic development. But what about the type of information these gestures convey? Speakers are known to combine different techniques when they depict referents in gesture (e.g., [8], [14]) and in pantomime (e.g., [15]). For instance, in describing a clock, a speaker may draw a circle in the air, or tilt an extended finger to the left and to the right, pretending the finger to be the clock hand. In her work, Müller [8] recognizes four basic representation modes, often employed by speakers in spontaneous gesturing. The hands *imitate*, when they pretend to use an imaginary object; they *portray*, when they pretend to be an object or character; they *draw*, when they trace a silhouette in the air; and they *mold* when they pretend to "sculpt" shapes. These techniques reveal information about how speakers conceptualize objects. Previous work has addressed the question of how specific object characteristics influence the choice of representation technique seen in speakers' gestures. For instance, Masson-Carro and colleagues [14] found that speakers used mostly imitating gestures when describing manipulable objects, than when describing non-manipulable objects, where they exhibited a tendency towards shape gestures. In this study, we expand this line of research by examining the influence of age on the choice of representation technique.

A few studies have addressed the use of representation techniques by children at different stages of language acquisition. Overton and Jackson [5] asked children aged 3, 4, 6, and 8 years old to pantomime the typical use of a series of common objects. Their study was one of the first to reveal a representational shift from "body part as object" gestures (using the index finger as a toothbrush –also called portraying gestures) to "symbolic" gestures (e.g., hand grabs imaginary toothbrush by handle, and pretends to brush teeth –also called imitating gestures). Thus, in about 80% of all the gestures observed in 3 year olds, children used their own body to represent objects, and this decreased the older children got, in favor of gestures where children pretended to use an object directly. By age 8, symbolic gestures constituted nearly 70% of the gestures produced by children, and body part as object gestures only the remaining 30%. Several studies have replicated this finding. For instance, Boyatzis and Watson [6] asked 3, 4 and 5 year olds to pretend to use 8 common objects, and also found a preference for body part as object gestures in 3 year olds (80%), but a preference for imaginary object use at age 5 (69%). In a second experiment, they explored the ability of these children to imitate a series of gestures executed by the experimenter, and found that younger children had trouble to reproduce imaginary-object gestures, in comparison with older children. A study by O'Reilly [7] showed that, at age 3, not only do children have trouble producing these imaginary-object gestures, but they also have trouble with comprehending these representations. In a narrative context, McNeill [2] describes a similar phenomenon. He examined cartoon retellings in children aged 2, 5, and 8, and compared their gestures with those produced by adults in the retelling of the same cartoons, to find that older children (aged 8) exhibited a mix of mature and immature gestural features, with a tendency to produce "enacting" gestures that was not found in adults. In conclusion, these studies show that during the first years of life, a cognitive shift takes place, as children begin to understand and produce (iconic) gestures, not purely as actions, but as communicative *symbols*. In this respect, gestures act as indicators of the transition from action to abstraction, from physical to conceptual knowledge; and this transition can be seen as a milestone in the development of symbolic thought.

1.3. The present study

In the present paper we ask the following question: Do children in late developmental stages use gestures entirely similarly to adults? We aim to find out by examining the gestural strategies employed by older children (mean age 9) in referential communication about objects, and comparing them with those employed by adults (mean age 25). Given that previous studies have shown that children and adults gesture differently about manipulable, and non-manipulable objects (e.g., [16], [14]), we will control for object-type by including "manipulability" as a variable in our design[1].

We examine gestural behavior in two communication modalities that differ in the extent to which they are tied to speech, namely speech and gesture (henceforth, speech), and gesture-only (henceforth, pantomime). Pantomimes, in the context of this study, are defined as gestures that occur in the absence of speech [2]. Like co-speech gestures, pantomimes are not conventionalized; however, unlike co-speech gestures, pantomimes must be sufficiently informative to be interpreted on their own. Thus, this allows us to make a first exploration of the techniques used by speakers in gesturing, not only at different developmental points, but also in different modalities, allowing us to gain insight into several aspects of gesture production, for instance, about the extent to which the choice of a representation technique is dependent on speech production.

2. Method

2.1. Participants

20 adults and 20 children participated in this study. The adults were students of Tilburg University (Mean age = 25.5 years, 7 male), and participated in exchange for partial course credit. The children taking part in this study (Mean age = 9 years, 10 male) were members of the Scouting Rambonnetgroep in Naaldwijk (The Netherlands) and participated voluntarily, after receiving written consent from their legal tutors. All participants were native speakers of Dutch.

2.2. Stimuli

The stimuli was composed by eleven manipulable objects (book, eraser, pencil, ruler, sharpener, stapler, scotch tape, scissors, calculator, brush and shovel), and eleven non-manipulable objects (tree, slide, sandpit, blackboard, table, school, chair, treehouse, clock, shelves, seesaw). Manipulable objects were defined as "objects operated with the hands, whose operation may induce a change in the physical world". For instance, the use of a pair of scissors typically results into the division of a sheet of paper into smaller units. All items were compiled into two presentation documents (one for manipulable, and one for non-manipulable objects), plus two counterbalanced versions. The stimuli were shown to the speakers by the experimenter on a 10'' Ipad, where the items were displayed full-screen. A digital video camera was placed behind the addressee, to record the speaker's speech and gestures.

[1] While we acknowledge the effect of *manipulability* is interesting in itself, its discussion falls beyond the scope of the present paper and thus we mainly focus on the influence of age and modality on gesturing.

2.3. Procedure

The experiment was carried out in pairs. Each pair was assigned to a condition, namely speech, or pantomime, in turns (e.g. A-B-A-B). The task was introduced to the participants as a guessing game, such like *Taboo* (in the speech and gesture condition), or *Charades* (in the pantomime condition). The procedure was as follows: Participant A described eleven objects (either manipulable or non-manipulable) to participant B, one by one. Participant B had to guess the name of the object being described, and say it out loud. Once the first eleven objects were described, roles were reversed, and participant B described the remaining eleven objects to participant A –for instance, non-manipulable objects, if participant A had described manipulable objects.

2.4. Data analysis

We annotated all the gestures produced by the speakers using the multimodal annotation tool Elan [17]. We classified gestures according to four main gesture types, namely iconic gestures [2], pointing gestures, interactive gestures directed at the addressee [18] and other (e.g., emblems, beats). All gestures were coded from preparation to retraction.

Next, we annotated all iconic gestures for representation technique. We annotated six representation techniques: *portraying*, *molding*, and *tracing* (based on Müller [8]), *enacting*, *object use*, and *object use + portray* (dual) (subdivision of Müller's *imitating* gestures). We added a seventh category to account for gestures that did not fit any other type, coded as *other*. Definitions and examples are provided in Table 1.

Table 1. Coding scheme for representation techniques

Representation Technique	Description
Object use	The actor simulates the performance of an object-directed action. Example: pretend to hold a pencil, and write
Portraying	The hand is used to portray an object, as if it had become the object itself. Example: the hand portrays a pair of scissors, with index and middle fingers stretched out, and simulates the action of cutting through paper.
Use & Portraying	One hand portrays an object, while the other performs an object-directed action. Example: one hand portrays a book, with a flat palm facing up, while the other hand pretends to turn the pages of the book.
Enacting	The actor simulates the performance of an intransitive action. Example: the whole arms swing back and forth in alternated movements, simulating the motion of the upper body while running.
Molding	The hand molds or sculpts the shape of an object. Example: a flat hand with the palm facing down moves along the horizontal axis, representing the "flatness" of an object's surface.
Tracing	The hand draws a shape in the air with a stretched index finger. Example: tracing a big square with the tip of the finger to represent a quadratic object such as a window.
Other	Gestures that do not fit other categories (e.g., using the fingers to count)

2.5. Design and statistical analyses

The effects of manipulability (manipulable, non-manipulable), age (children, adults), and modality (speech, pantomime) on our dependent variables (gesture rate, and representation technique) were assessed using linear mixed models for continuous variables (i.e., gesture rates), and logit mixed models for categorical variables (i.e., representation techniques) (see [19]). In all of the analyses, participants and items were included as random factors. Due to space limitations, our results section will only report test values for significant results.

3. Results

The communication task generated 420 descriptions, containing a total of 1497 gestures. Iconic gestures accounted for 74% (1098) of the gestures annotated, the remaining 26% consisting of other gesture types (deictics 6%, interactive gestures 12%, and other gestures 8%). With the exception of iconic gestures (discussed below), the type of gestures produced by speakers was not influenced by age, manipulability, or modality. The remainder of this section focuses on the iconic gestures produced by speakers.

3.1. Analysis of iconic gesture rate

We analyzed the effects of our independent variables on the mean number of iconic gestures produced per description. Not surprisingly, we found a main effect of modality ($\beta = -3.6205$, $SE = 0.48$, $p < .001$), indicating that speakers who accomplished the task in the pantomime condition (no speech) produced more gestures ($M = 4.34$, $SD = 3.67$) than speakers who could both speak and gesture ($M = 1$, $SD = 1.97$). We found no main effects of age on the production of iconic gestures, but a significant interaction between age and modality ($\beta = -1.64$, $SE = .77$, $p < .001$), showing that children produced more gestures than adults in the pantomime condition, but less gestures than adults in the speech condition (see Figure 1). In contrast to [14], we found no evidence that children or adults gestured more frequently about manipulable than about non-manipulable objects

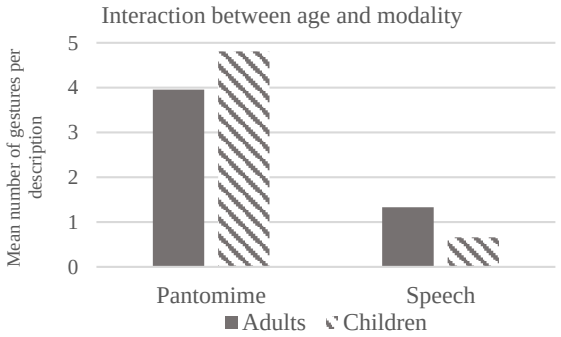

Figure 1: *Mean of gestures per description produced by older children and adults, in the pantomime and speech conditions. (Interaction significant at $p < 0.001$)*

3.2. Analysis of representation techniques

Our analyses of the representation techniques yield interesting insights. First of all, molding and object use were the most preferred techniques used to represent objects gesturally, together accounting for 60% of all gestures produced. Both age (Figure 2) and manipulability influenced the use of several techniques to represent objects. Age was found to influence the preference for object use gestures, whereby the speaker pretends to carry out an object-directed action ($\beta = .83$, $SE = .37$, $p < .05$), with children exhibiting more object use gestures ($M = .45$, $SD = .49$) than adults ($M = .4$, $SD = .49$). Similarly, children also used more object use gestures in combination with portraying gestures ($M = .11$, $SD = .18$) than adults ($M = .03$, $SD = .31$) ($\beta = 1.7$, $SE = .37$, $p < .001$). In contrast, adults exhibited more molding gestures ($M = .24$, $SD = .42$) than children ($M = .18$, $SD = .38$) ($\beta = -.84$, $SE = .4$, $p < .05$).

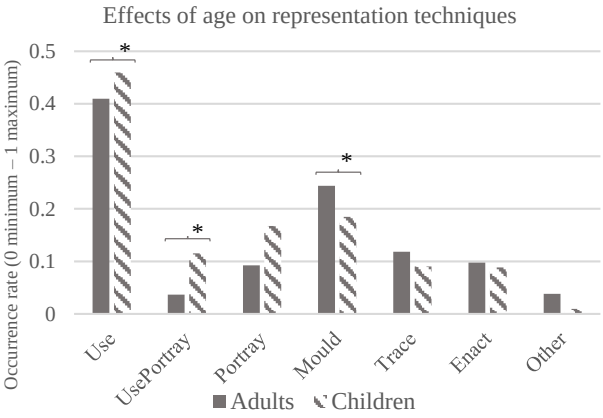

Figure 2: *Effect of age on the representation techniques*. **Significant at $p < 0.05$, **significant at $p < 0.001$.*

There was no main effect of modality, but several interactions were found in the data between age and modality (Figure 3). It is interesting to note that all three interactions occur at the level of speech. While no differences are observed for pantomime, in speech we find that children produced more enacting ($\beta = -2.46$, SE = .88, $p < .01$) and (marginally) more object use gestures ($\beta = -1.1$, SE = .58, p = .059) than adults. The opposite pattern is found for molding gestures, where adults produced more gestures than children ($\beta = .99$, SE = .46, $p < .05$).

As expected, manipulability affected the choice of representation technique. Object use gestures accompanied more often manipulable ($M = .69$, $SD = .45$) than non-manipulable objects ($M = .18$, $SD = .39$) ($\beta = -3.41$, $SE = .77$, $p < .001$), and the same was found for gestures where object use was combined with portraying gestures ($\beta = -3.14$, $SE = 1.42$, $p < .05$ [manipulable $M = .13$, $SD = .34$; non-manipulable $M = .01$, $SD = .12$]). In contrast, non-manipulable objects were more often gestured by using molding ($\beta = 1.87$, $SE = .46$, $p < .001$ [manipulable $M = .09$, $SD = .29$; non-manipulable $M = .32$, $SD = .46$]), tracing ($\beta = 1.87$, $SE = .46$, $p < .001$ [manipulable $M = 0.6$, $SD = .24$; non-manipulable $M = .14$, $SD = .35$]), and enacting gestures ($\beta = 2.71$, $SE = 1.18$, $p < .05$ [manipulable $M = .007$, $SD = .08$; non-manipulable $M = .17$, $SD = .37$]). Lastly, manipulability did not interact with age, or modality, showing that its effects on the representation techniques used are independent.

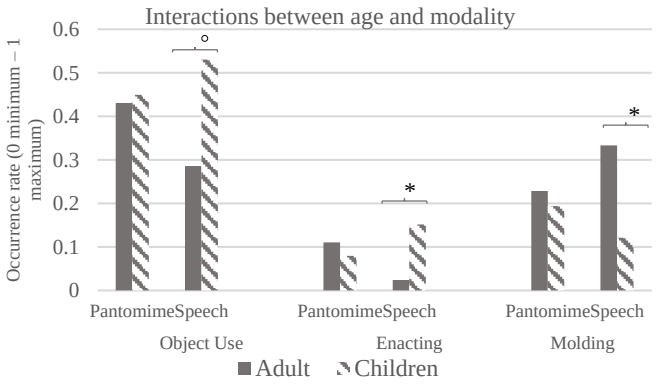

Figure 3: *Interactions between age and modality regarding the use of representation techniques. *Significant at $p < 0.05$, **significant at $p < 0.001$, ° <.1.*

4. Discussion

In the present study, children and adults were asked to either pantomime (only gesture) or verbally describe (speech and gesture) a series of items to a peer. We measured the occurrence of iconic and non-iconic gesture types, and annotated the representation techniques that speakers used to convey meaning. In addition, we also manipulated the type of objects that had to be described, by including manipulable, and non-manipulable objects.

We first looked at the type of gestures produced by speakers. We analyzed the type of gesture used, and found that the vast majority of the gestures produced by both children and adults were iconic. This means that other gesture types, such as deictics (which constituted a 6% of all the gestures annotated), were performed to the same extent both by children and adults, regardless of the communication modality and object type. These results extend the findings by previous studies, for instance Stefanini et al. [12], who showed a decrease in pointing gestures between the ages of three and four, with already low deictic rates by the age of 6;4. Thus, it appears that around the age of 9 the use of pointing gestures has decreased to adult-like levels, at least for referential tasks in which pointing is not required. Both in the speech and pantomime conditions, for instance, children still used pointing to directly refer to the location of referents outside the room (e.g., to indicate the trees outside, or the blackboard downstairs). The same was observed in adults, but adults displayed a type of pointing that children did not, namely they pointed directly at their own gestures to highlight or clarify what the referent was. For instance, in portraying gestures where the hand pretended to be an object, speakers often used the other hand to point at the portraying hand, to indicate that it is not the action but the object what was relevant.

The remainder of the discussion section, we focus on iconic gestures. We found that participants produced more iconic gestures in the pantomime than in the gesture condition. This did not come as a surprise, as in the pantomime condition the use of gestures was obligatory, whereas in the speech condition no instructions were given concerning the use of gestures, so gestures are assumed to have arisen spontaneously. We found an interaction between age and modality, meaning that children gestured more than adults in the pantomime condition, but less than adults in the gesture condition. The differences in the amount of pantomimes produced by children and adults can be seen as a reflection of task difficulty. It took children more gestures to be understood by their addressees, and some children explicitly reported that they found the pantomime task

hard. It may be the case that children still need to learn to fully exploit the expressivity offered by the manual modality, and are unsure in selecting the features of the target referent that will be easiest to represent with the hands, and also best understood by their addressees. Concerning the production of speech-accompanying gestures, our study showed that older children gesture at lower rates than adults. This is consistent with previous research. For instance, in the context of a narrative task, Mayberry, Jaques and DeDe [20] compared the amount of words accompanied by gestures produced by stuttering and non-stuttering older children (mean age = 11) and adults. The results for the non-stuttering control group showed that adults accompanied their speech with gestures almost three times as much as children did. Using a narrative task, Alibali and colleagues [13] also found children to gesture less than adults, although these differences did not prove statistically significant. Altogether, it seems that older children gesture to a lesser extent than younger children [21] and also than adults, as shown by the present study and suggested by previous research [20]. This U-shaped pattern in gesture production may be an indicator of the ever-changing relationship between speech and gesture, with gesture production oscillating between higher and lower peaks until the relationship between the two modalities becomes fully consolidated, possibly in adolescence. In sum, we conjecture that, while younger children may use gestures as anchors to coordinate their representations, in late childhood gestures have become optional, and children do not fully regard their gestures yet as communicative devices that can be relied upon in order to communicate more efficiently.

Lastly, it is interesting to note that manipulability did not influence the amount of iconic gestures produced by speakers. Previous studies have shown that objects that are manipulable are more often gestured about than objects which are not, and this was found to be the case both for children [16] and for adults [14]. The explanation for this phenomenon is that manipulable objects may evoke action simulation, which could in turn prime gesturing in speakers (see [22]). In this study, we could have expected both groups to gesture more about manipulable objects in the speech condition. However, that is not what we found. One tentative explanation for this finding is that non-manipulable objects may have been harder to describe than manipulable objects, which could have increased the gesture rates for non-manipulable objects, to facilitate their description.

4.1. Representation techniques

Our study revealed different patterns regarding how older children and adults used gestural techniques to represent objects. Perhaps the most striking finding is that these differences were only found for spontaneous gesture production (recall Figure 3), indicating that in pantomime both adults and children represented objects similarly. Pantomimes, unlike other gesture types such as emblems (e.g., the thumbs-up sign), are not given by convention. However, a recent study by Van Nispen and colleagues [15] found regularities in the use of pantomimes (by adults) in the communication about objects, suggesting that speakers share to a certain extent similar mental representations. Our study extends these findings by showing that adults and children use representation techniques similarly when pantomiming. Furthermore, we observed the occurrence of combinatorial patterns in both groups. For instance, in depicting a sandpit, gesturers would typically produce a shape gesture (e.g., tracing the shape of the sandbox) followed by an action gesture (e.g., pretending to use a shovel). These examples highlight how, in the absence of speech, pantomimes begin to adopt consistent combinatorial patterns (e.g., first shape, then action), as suggested by [2], and also [23].

With respect to the age differences in spontaneous gesture production, we found that older children had a tendency towards producing more action gestures (whether transitive –object use- or intransitive –enactment-) than adults, who produced more shape gestures (in this case, molding gestures) than children. Furthermore, if we zoom into the techniques used by children (recall Figure 2), we can see that children produced twice as many object use gestures than portraying gestures, and in general twice as many action gestures than shape (molding or tracing) gestures. In adults, these differences were less pronounced. Therefore, although older children have left behind the phase where they represent objects and tools by using their own body as a cognitive anchor (as evidenced by younger children's preference for body-part-as-object gestures [5], [6], our results indicate that older children still have a preference for action-based [24] forms of iconicity, in contrast to perceptually-based [24] forms of iconicity, more present in the gestures produced by adults. This is interesting, if we consider how different gestural techniques vary in terms of their schematic complexity [24]. For instance, action gestures are closer to daily sensorimotor experience and seem relatively less schematic than perceptually-based shape gestures, which undergo a greater process of abstraction. Our results suggest that children are able to use more abstract representation techniques when gestures are consciously and deliberately produced (as is the case in pantomime) but perhaps they find action-based gestures easier to produce and therefore rely more on these when speech is the main communicative modality, and gesture production is optional.

The fact that there were no effects of modality on the representation techniques used is remarkable. Few studies have provided a systematic overview of the key differences between pantomiming and gesturing. Our study shows that whereas both forms of gesturing are non-conventionalized, speakers typically converge in the ways they gesture about objects, and come to use similar techniques. This could mean that both pantomimes and gestures, although constrained by language to different extents, emerge from the same representations. Thus, it could be the case that speakers (at least speakers who share the same language) have a natural tendency to converge in the iconic strategies they use to encode concepts into representational hand gestures, and that this process is free of the influence of (concurrent or not) speech.

4.2. Future research

The current study has a number of limitations. For instance, the scope of our analyses. While we were interested primarily in the gestural techniques that are used to convey meaning, there are other aspects of gesture production that are susceptible to the effects of age, and modality. For instance, we did not examine whether children used more whole-body gestures than adults (as suggested by McNeill [2]) or whether they tended to repeat the same gestures within one description, instead of combining different forms. Future studies could address these issues, to get a more complete picture of the development of the gestural system. Ultimately, the question should be asked whether these differences have an impact on how addressees interpret the meaning of utterances.

As for modality, we did not compare whether pantomimes were larger, or more precise, than gestures produced alongside speech, as one could expect if we take into account that, in pantomime, gestures are the sole vehicle for meaning expression, and their form may be enhanced for communicative purposes. Instead, we studied the techniques that speakers used to express information gesturally, and thus we can say something about the type of information that gestures conveyed, but we did not examine whether gestures and

pantomimes really depicted the same, or different, features of objects. For instance, both a pantomime and a co-speech gesture might have outlined a shape for one particular object, but perhaps the shape depicted corresponds in each case to a different salient feature of the object. In future studies we plan to expand our dataset and look into these aspects.

5. Conclusions

In conclusion, this study showed a number of differences regarding how older children (aged 9) and adults use gestures in referential communication. When speaking was forbidden, and children could only rely on their hands to describe objects, they needed more gestures than their adult counterparts to complete the task. However, their gestures exhibited the same range of representation techniques to express meaning as adult gestures did. In contrast, when speaking was allowed, children relied less on gesturing than adults, and exhibited a bias towards producing action gestures, such as enactments, or imaginary object use gestures. Adults, in contrast, exhibited a wider range of techniques to help meaning come across, and relied on object use and shape gestures to a similar extent. This suggests that older children may already have all the tools needed for full gestural expressivity (as observed in the pantomime condition), but do not use them as smoothly as adults when speech and gestures are co-produced, indicating that both modalities haven't become fully integrated yet.

In addition to this, our study confirmed that, despite playing different (primary or secondary) communicative roles, co-speech gestures and pantomimes reflect similar aspects of the speakers' mental representations, and rely on the same techniques to encode information.

6. Acknowledgements

We thank Mirthe Treurniet for the help in collecting and annotating the children dataset. We received support for this research through a grant awarded by The Netherlands Organisation for Scientific Research (NWO) [grant number 322-89-010], which we gratefully acknowledge.

7. References

[1] Goldin-Meadow, S., "Widening the lens: what the manual modality reveals about language, learning and cognition", Philosophical Transactions of the Royal Society B: Biological Sciences, 369(1651), 2014.

[2] McNeill, D., "Hand and mind: What gestures reveal about thought", Chicago: University of Chicago Press, 1992.

[3] Iverson, J. M., and Goldin-Meadow, S., "Gesture paves the way for language development", Psychological science, 16(5): 367-371, 2005.

[4] Gullberg, M., De Bot, K., and Volterra, V., "Gestures and some key issues in the study of language development." Gesture, 8(2):149-179, 2008.

[5] Overton, W. F., and Jackson, J. P., "The representation of imagined objects in action sequences: A developmental study", Child development, 44(2):309-314, 1973.

[6] Boyatzis, C. J., and Watson, M. W., "Preschool children's symbolic representation of objects through gestures", Child development, 64(3):729-735, 1993.

[7] O'Reilly, A. W., "Using representations: Comprehension and production of actions with imagined objects", Child development, 66(4):999-1010, 1995.

[8] Müller, C., "Iconicity and Gesture", in S. Santi, I. Guatiella, C. Cave and G. Konopczyncki [Eds.], Oralité et Gestualité. Montreal, Paris: L'Harmattan, 1998.

[9] Capirci, O., Contaldo, A., Caselli, M. C., and Volterra, V., "From action to language through gesture: A longitudinal perspective", Gesture, 5(1-2):155-177, 2005.

[10] McNeill, D., "Gesture and thought", Chicago: University of Chicago Press, 2008.

[11] Mayberry, R. I., and Nicoladis, E., "Gesture reflects language development evidence from bilingual children", Current Directions in Psychological Science, 9(6):192-196, 2000.

[12] Stefanini, S., Bello, A., Caselli, M. C., Iverson, J. M., and Volterra, V., "Co-speech gestures in a naming task: Developmental data", Language and cognitive processes, 24(2):168-189, 2009.

[13] Alibali, M. W., Evans, J. L., Hostetter, A. B., Ryan, K., and Mainela-Arnold, E., "Gesture–speech integration in narrative: Are children less redundant than adults?", Gesture, 9(3):290-311, 2009.

[14] Masson-Carro, I., Goudbeek, M. B., and Krahmer, E. J., "Can you handle this? The impact of object affordances on how co-speech gestures are produced", under review.

[15] Van Nispen, K., van de Sandt-Koenderman, M., Mol, L., and Krahmer, E., "Pantomime Strategies: On regularities in how people translate mental representations into the gesture modality", in P. Bello, M. Guarini, M. McShane, and B. Scassellati (Eds.), Proceedings of the 36th Annual Conference of the Cognitive Science Society, Austin, TX: Cognitive Science Society, 976-981, 2014.

[16] Huttunen, K. H., Pine, K. J., Thurnham, A. J., and Khan, C., "The Changing Role of Gesture in Linguistic Development: A Developmental Trajectory and a Cross-Cultural Comparison Between British and Finnish Children", Journal of psycholinguistic research 42(1):81-101, 2013.

[17] Wittenburg, P., Brugman, H., Russel, A., Klassmann, A., and Sloetjes, H., "ELAN: a professional framework for multimodality research", in Proceedings of LREC, Fifth International Conference on Language Resources and Evaluation. Paris: ELRA, 2006.

[18] Bavelas, J. B., Chovil, N., Lawrie, D. A., and Wade, A., "Interactive gestures." Discourse processes, 15(4):469-489, 1992.

[19] Jaeger, T. F. "Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models", Journal of memory and language, 59(4):434-446, 2008.

[20] Mayberry, R. I., Jaques, J., and DeDe, G., "What stuttering reveals about the development of the gesture-speech relationship", New Directions for Child and Adolescent Development, 79:77-88, 1998.

[21] Bello, A., Capirci, O., and Volterra, V., "Lexical production in children with Williams syndrome: Spontaneous use of gesture in a naming task", Neuropsychologia, 42(2):201-213, 2004.

[22] Hostetter, A. B., and Alibali, M. W.,"Visible embodiment: Gestures as simulated action", Psychonomic Bulletin and Review, 15:495–514, 2008.

[23] Goldin-Meadow, S., So, W. C., Özyürek, A., and Mylander, C., "The natural order of events: How speakers of different languages represent events nonverbally", Proceedings of the National Academy of Sciences, 105(27):9163-9168, 2008.

[24] Perniss, P., and Vigliocco, G., "The bridge of iconicity: from a world of experience to the experience of language." Philosophical Transactions of the Royal Society B: Biological Sciences, 369(1651), 2014.